NATIONAL BUREAU OF STANDARDS REPORT

9506

Final Report

of

Arcata Field Tests for Atmospheric Backscatter Signature Studies

By

J. W. Simeroth
James E. Davis
J. C. Wilkerson

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

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NBS PROJECT **NBS REPORT**

2120653 March 1967 9506

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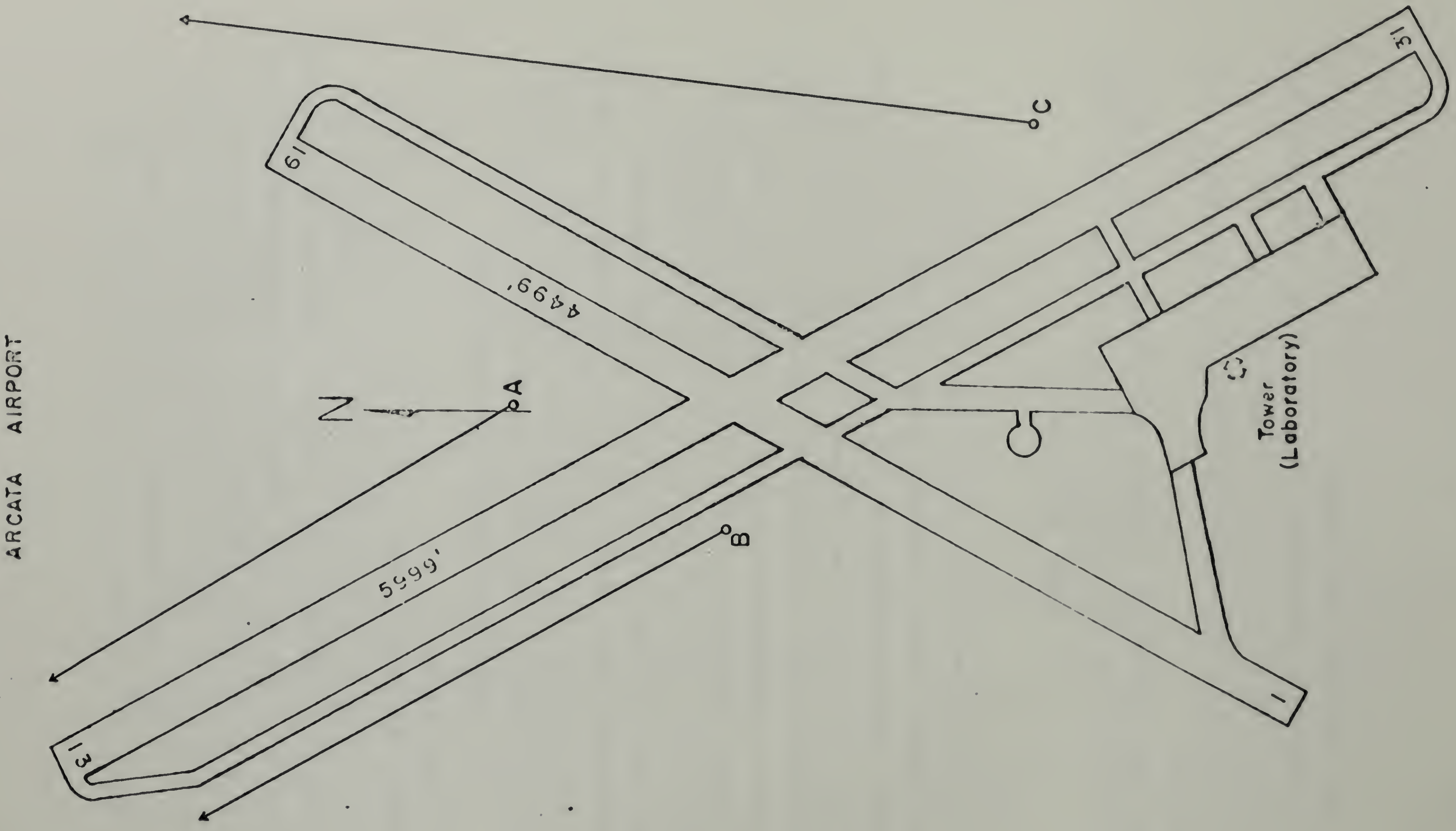


Figure 1. The Arcata Airport with the sites which were considered for the installation identified.

C. To install the tower for mounting the laser equipment and the shelter to protect this equipment. The tower and shelter were furnished by the non-government contractor.

D. To provide working space for personnel and equipment which would be separated from the laser. An available house trailer was moved to a position adjacent to the laser for this purpose.

E. To furnish electrical power at the site for the laser and at the working space.

F. To provide communications between the working space and the NBS office, FAA Flight Service Station (FSS), and other organizations as required for tests of the laser.

3. INSTALLATION

3.1. Site

The site which was selected and approved for this project located the laser just behind the ILS glidepath building for the approach to runway 31. The axis of the laser beam was aimed approximately true north across the approach to runway 19. The instrument positions are shown in figures 2 and 3. The first 2900 feet of the range is on the airport property, where the ground is nearly level and is clear of trees or structures for several hundred feet on either side of the beam. Beyond the airport, the range crosses a creek and low area, then a ridge with an elevation slightly below the axis of the laser beam, then passes in the vicinity of some tall trees, and terminates at a hill approximately five miles from the laser.

3.2. Laser Installation

The major shipment of the laser equipment, including the tower and shelter, was received on August 18. The cable to supply power to the site was installed on August 23. Messrs. Richard Hazel and Robert Doughty of Sperry Rand Research Center, arrived on August 29. On August 31 the laser tower was erected and the instrument shelter installed. A 30-foot house trailer was moved into position beside the laser on September 1 to provide the working space. Limited electrical power to the laser shelter

Figure 2. Installation layout for the laser tests at Arcata, California.

Figure 3 Aerial View of Laser Test Bed at Arcata Airport

and the trailer was provided on September 2. Temporary power with adequate capacity to check the laser was provided on September 9. A 25-kilowatt distribution transformer, furnished by FAA, was received on September 11 and the full power installation was completed on September 12. Operation of the laser for checks and alinement was started on September 13 by Sperry Rand personnel and was completed on September 17. Final alinement and checks awaited atmospheric conditions suitable for testing. These adjustments were made during a period of fog on September 30.

3.3. Transmissometer Installations

Three 250-foot-baseline transmissometers were supplied by the National Bureau of Standards. The midpoints of these baselines were 625, 1375, and 2075 feet from the laser. The transmissometers are identified as T-L1, T-L2, and T-L3, respectively. See figure 2. (Transmissometers T-S, T-F, and T-H are existing NBS instruments with 500-foot baselines. Transmissometer T-D is the Weather Bureau transmissometer (also with a 500-foot baseline) for runway 31.) The projectors and receivers were mounted on 14-foot stands, which put these units at approximately the same elevation as the laser. Signal lines from these units were connected to indicators in the laboratory. The signal from T-L1 was also connected to a portable indicator in the trailer to provide a record at the test site. The installation of these transmissometers was completed on September 14.

The indicators for the newly installed transmissometers were affected by crosstalk on the signal lines. To eliminate this crosstalk, an isolating transformer was used to connect each indicator to its signal line. By connecting the isolating transformer to the ZERO switch on the indicator, and leaving the BACKGROUND switch, input capacitor, and choke connected directly to the signal lines, the crosstalk was satisfactorily reduced and the hourly check and background check functions were retained.

A "photopack" unit was furnished by the FAA for photographically recording the pulse counts from the 250-foot-baseline transmissometers. This photopack consisted of three electronic digital counters which counted the pulses from the transmissometers for 55 seconds of each minute and a 35-millimeter camera which recorded photographically the pulse count, the time, and the date at the end of each counting period. The signals for the counters were taken directly from the signal lines. Crosstalk affected the operation of these counters until filter circuits were installed. The filters consisted of 4000-ohm potentiometers in one side of each signal pair and a 0.01-microfarad capacitor between the ground side of the signal pair and the counter input. The capacitors served to eliminate the common ground of the counters and to attenuate the crosstalk. The potentiometers were adjusted to reduce the crosstalk to levels which would not trigger the counters.

As noted earlier, four additional transmissometers located as shown in figure 2 were in the vicinity of the test range for the laser. The field units of T-D were mounted on 14-foot stands and the other units were mounted on 7-foot stands. The measurements from these transmissometers were supplemental to the data from the 250-foot-baseline units and were available in the event of a malfunction of a new unit during a test.

3.4. Visibility Range

A range for observations of the visual range of visibility targets was established in the area of the laser test range. This observation range was intended primarily for another project, but the observations were timed to agree with the taking of the laser data points. These observations were used for correlating information in the data analysis. This range is 1900 feet long and crosses the axis of the laser beam at a small angle approximately 1200 feet from the laser. The observer was located approximately 350 feet from the laser on a fixed stand which put his eye level at the elevation of the 250-foot-baseline transmissometers.

The targets were mounted on a vehicle. The center of the targets was 14 feet above the ground. The targets were (1) a 5-foot by 5-foot black target for daytime observations and (2) a 25-candela light at the center of the daytime target for nighttime observations.

3.5. Communications

A two-way F-M radio transceiver was installed in the trailer to provide communications on the Airport for the laser test group. This radio provided contact from the test site to the NBS Field Laboratory, the FAA Flight Service Station, and the NBS vehicles.

4. TESTING

4.1. Conditions of Testing

The purposes of the laser tests were (1) to determine the characteristics of the backscatter returns from the laser pulses in various low visibility conditions and (2) to determine the effects on the signal of changes in certain design parameters of the equipment. The ruby rod laser fired a pulse of light along the test range. The backscatter from the pulse of light was detected by a photomultiplier device located near the laser, and the signal from the photomultiplier was presented on an oscilloscope. Certain qualities of the atmospheric extinction coefficient can be evaluated from the timing and shape of the backscatter signal. The data were recorded by photographing the oscilloscope trace of the back-scatter signal from a laser pulse with a Polaroid camera. Data points consisted of a series of eight photographs of pulses spaced at approximately five-second intervals. Data points were taken originally at three-minute intervals, but for most of the testing the intervals were two minutes. The test plan called for some 1200 data points--9600 photographs.

The atmospheric condition required for these tests was an atmospheric transmittance over a 250-foot baseline of less than 0.7. For two phases of the test, studies of the effect of receiver field of view and of separation between the laser and the receiver, the transmittances should range down to less than 0.04 and should include both day and night

conditions for each of the parameter conditions. For the third phase, tests at several power levels, stable fog conditions were needed.

4.2. Periods of Testing

Final checking and alinement of the laser equipment was completed on September 30. The periods when testing for evaluation was done were as follows:

Date (1966)	Time (PST)	Range of Transmittance (250-foot Baseline)	Date (1966)	Time (PST)	Range of Transmittance (250-foot Baseline)
10/3	1200-1430	.21 - .95	10/24-25	2240-0030	.016 - .67
10/3	1730-2230	.21 - .90	10/25	0800-1015	.024 - .80
10/4	0030-0230	.35 - .72	10/27	0720-0900	.22 - .89
10/9	0700-0945	.18 - .91	10/27	0945-1020	.63 - .88
10/18	1530-1545	.19 - .90	10/27-28	2315-0040	.31 - .77
10/19	1300-1400	.15 - .95	10/28	1940-2040	.010 - .81
10/19	1415-1520	.45 - .95	10/28	2120-2220	.030 - .66
10/22	1700-2045	.40 - .87	10/29-30	2230-0045	.025 - .30
10/22-23	2130-0030	.07 - .91	11/2	0700-1100	.006 - .82
10/23	1630-2330	.015- .78	11/4	0930-1200	.018 - .87
10/24	0945-1115	.07 - .71	11/5	1800-1900	.83 - .89
10/24	1800-2000	.25 - .93			

4.3. Visual Range Observations

Observations of the visual range of visibility targets were made during most of the laser tests. The observer directed the driver of the vehicle to move the target along the range positioning it until the target was at the observer's visual threshold. These observations were timed to agree with the time of taking of data points for the laser tests. The vehicle driver determined the distance to the observer from his position. To reduce bias the observer was not informed of the visual range or of the transmittance. The values of transmittance of the 250-foot baseline transmissometers at the time of the observation were recorded. The 1900-foot length of the range prevented observations when transmittance (over a 250-foot baseline) was higher than 0.6 in daytime or 0.3 at night. Visual observations were not taken during periods of twilight.

4.4. Transmissometer Data

The transmissometers performed well throughout the test period. The analogue chart records were marked for all correction factors for each test period. The three 250-foot baseline transmissometers frequently indicated appreciable differences in transmittance. The 500-foot-baseline transmissometers were maintained and the records for T-D, located between the laser and the projector of T-L1, were made available to Sperry Rand for use in analyzing the laser results.

The digital counters performed well after the input signal circuit was modified and adjusted to eliminate the effects of crosstalk. The camera was operated during test periods and the film was forwarded to Sperry Rand Research Center. After processing the first two rolls of film, it was found that most of the film had not been exposed. Investigation revealed that a riveted-in pin on which the shutter release arm rotated had loosened, allowing the release arm to slip by the shutter-release solenoid trip. Because of this malfunction, only about 20 percent of the digital data was recorded by the camera.

5. DISCUSSION OF TESTING

5.1. Results in Clear Weather Conditions

In clear weather the backscatter of the laser beam gave a signal similar to that expected--a gradual increase and decrease without a definite peak. The reflection from fixed objects indicated the range of the beam. The first definite reflection came from 3000 feet, apparently from a tree across the road from the airport property. This tree was to the right of the axis of the beam. A reflection at 6000 feet was from a barn and trees to the right of the beam. At approximately 10,000 feet there was a third fixed peak which apparently was caused by the beam entering a group of trees. The final object detected was at five to seven miles where the hills intercepted the beam.

5.2. Results in Test Conditions

The trace of the laser receiver signal in limited visibility conditions has a rapid rise to a peak then a more gradual decrease. The precise shape is determined by the atmospheric conditions through which the pulse is transmitted. For most conditions, the denser the fog the earlier the rise in the pulse starts, the earlier the peak comes, and the more rapidly the decrease occurs. In variable fog conditions at Arcata the trace sometimes had more than one peak, but almost always the major peak was very definite.

One characteristic of fog shown by these traces were that the conditions were continually changing even when the fog appeared stable and relatively uniform. This change was apparent not only between data points (two minutes) but frequently between individual pulses (five seconds). In unstable conditions, the changes in five seconds were often quite marked.

5.3. The Data Collected

Approximately 1000 data points were obtained. The number of data points obtained for some parameter settings of the laser was less than the desired 200 because in the early part of the test program there were doubts of getting sufficient fog to complete the test plan. All phases of the test plan were completed.

5.4. Transmissometer Data

The corrections for the analogue records were noted and were furnished to Sperry Rand for use in analysis of the laser data.

Usually the three 250-foot-baseline transmissometers showed differences in atmospheric transmittance. Seldom in fog conditions were the three transmissometers in close agreement. Even in apparently stable, uniform fog conditions including dense fogs, any one unit might indicate changes which did not appear at other units. Some systematic effects were detected. Recognizable patterns of movement were not easily evident either with time, location, or direction of movement.

5.5. The Test Bed

The range was adequate for the tests of the laser in the atmospheric conditions specified. This range was without obstructions for sufficient distance to test in much clearer conditions but additional transmissometers for correlating data would be needed and installation at suitable locations might not be practical. For the conditions of these tests, the three transmissometers spaced along the range provided transmittance measurements satisfactory for correlating with the laser results. The marked differences which frequently occurred as indicated by the transmissometers show that the complete picture of the fog conditions cannot be fully determined from measurements at only the three locations. Examples of indicated differences are shown by comparing the records in figures 4 and 5. A better picture of conditions could be obtained if the transmittance were measured in continuous short intervals along the range. The uncertainty of the transmittance in the unmeasured intervals between transmissometers was more noticeable when comparing observed visual range to the transmittance values than in correlating with the laser results. However, in very dense fog when the laser backscatter was effectively from only a short distance, the transmittance at T-L1 might be much different from conditions nearer the laser. Fortunately, the records from T-D were available to supplement the data from T-L1 in this area.

5.5.1. Use for Fog Variability Study. The test bed was very convenient for visual observations. This test bed provided data on the variability of coastal fogs. Examples of these variable fogs are shown in figures 5 and 6. At times these fogs can be fairly stable as in the dense fog shown in figure 7, or change slowly but similarly at the different locations, as shown for moderate fog in figure 8. As shown by these examples, a transmittance measurement at a given time and location may be a poor indication of conditions at another position on the airfield or at the same location a few minutes difference in time.

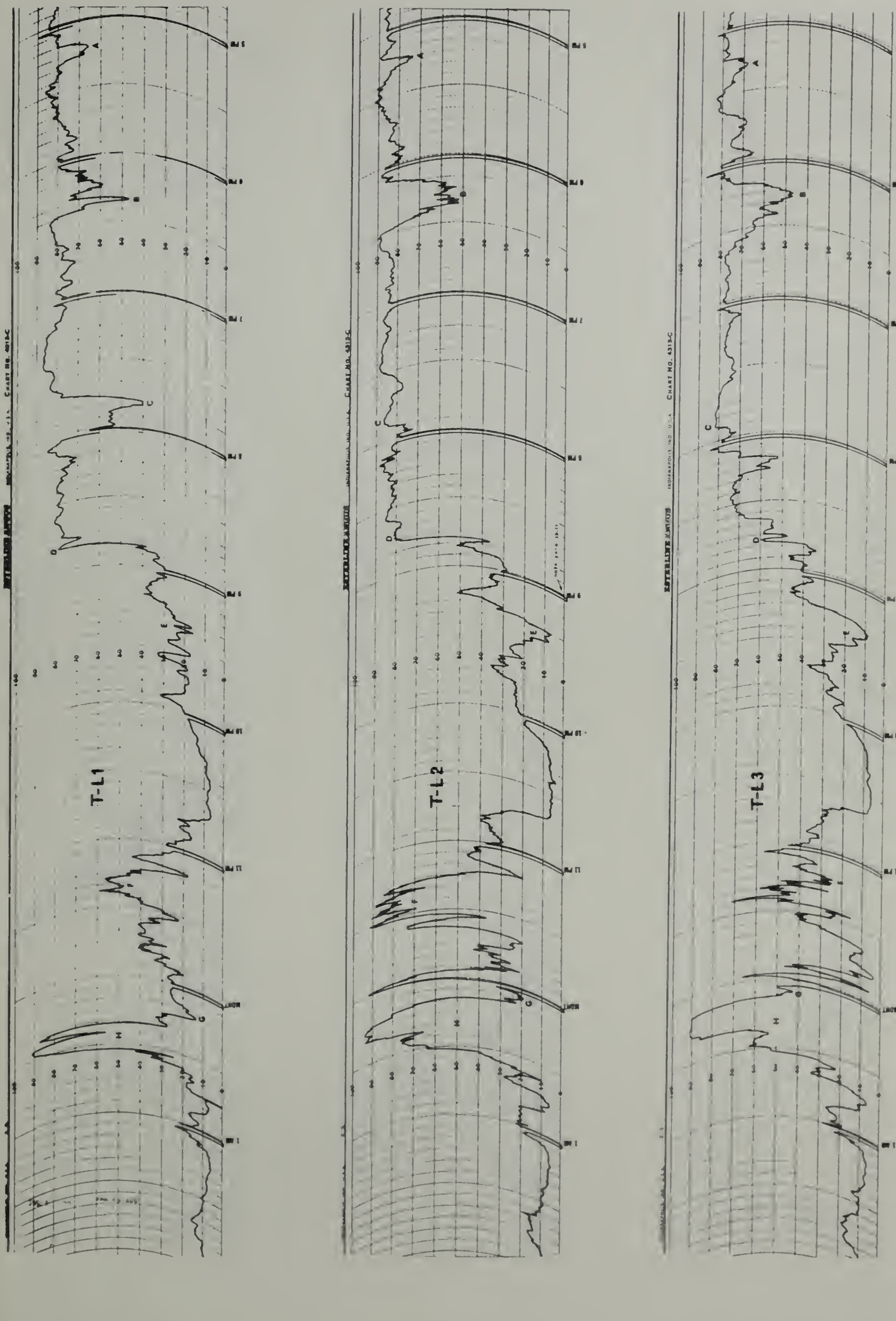


Figure 4 Fog of October 22-23,1966, an example of records showing variations in fog density at the locations of the transmissometers.
(The letters identify points of pronounced differences.)

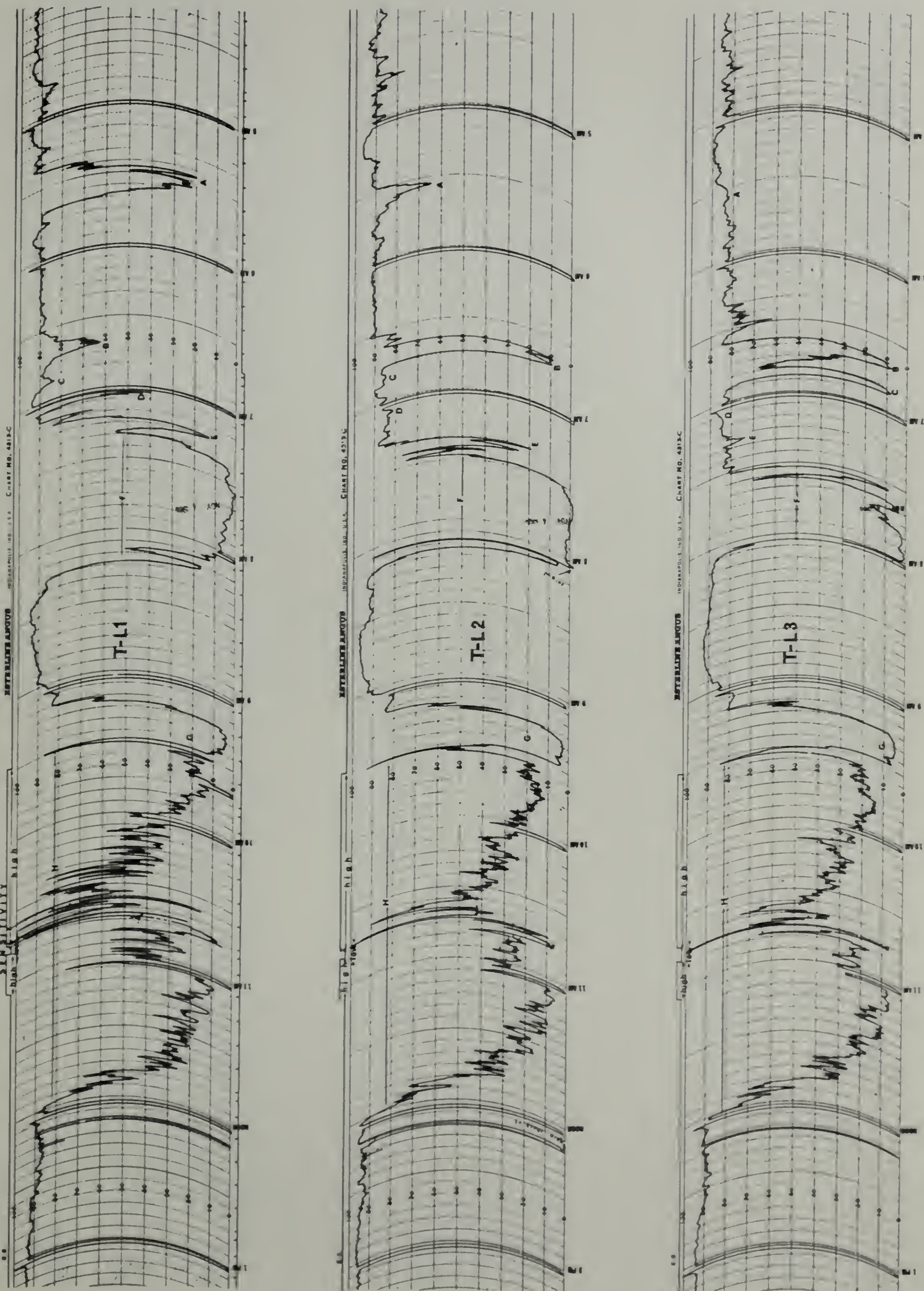


Figure 5 Fog of November 4, 1966, an example showing variations in fog density at the locations of the transmissometers and also rapid changes with time.

(The letters identify points of interest.)

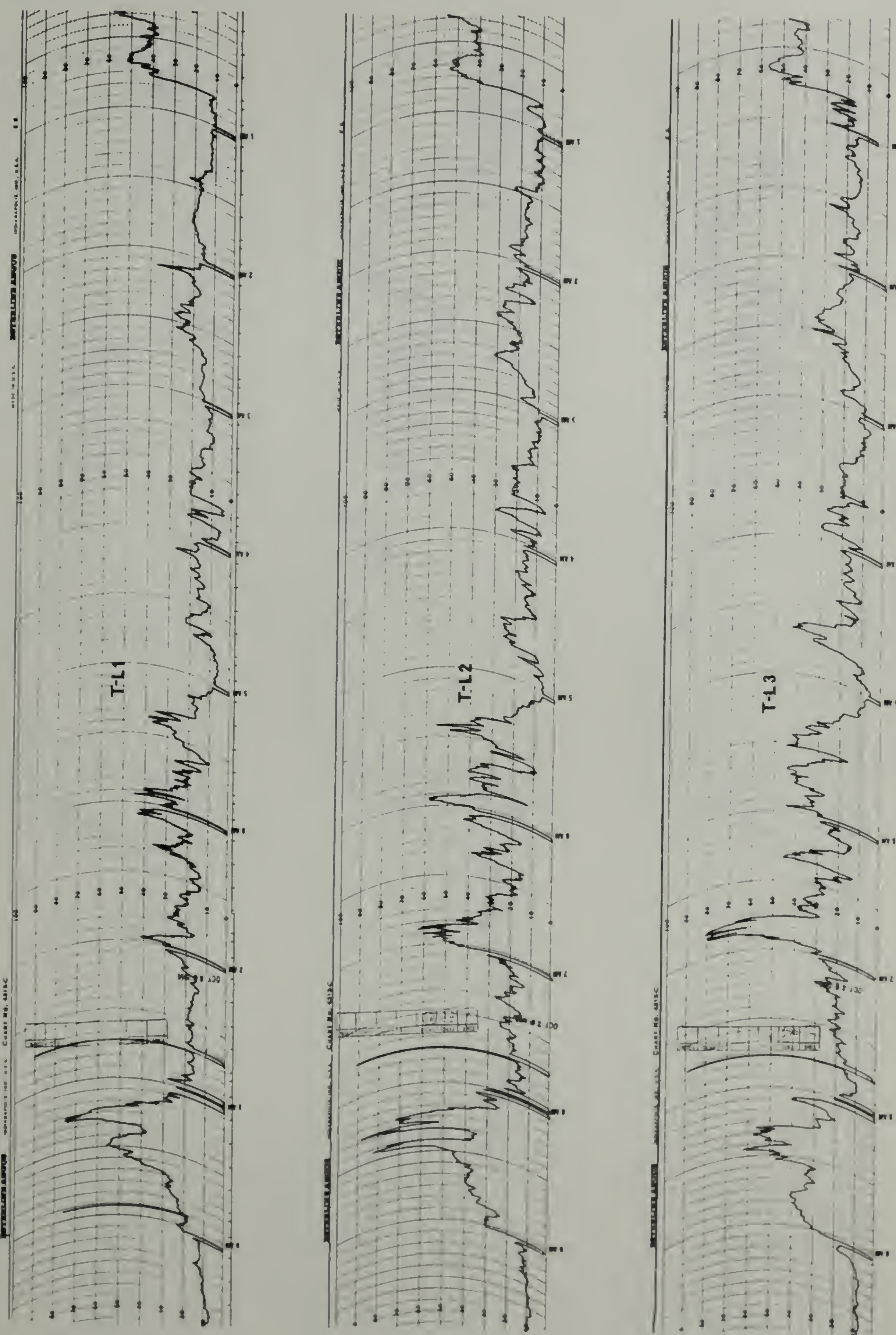


Figure 6a Fog of October 24, 1966, an example of rapid variations in fog density with time.

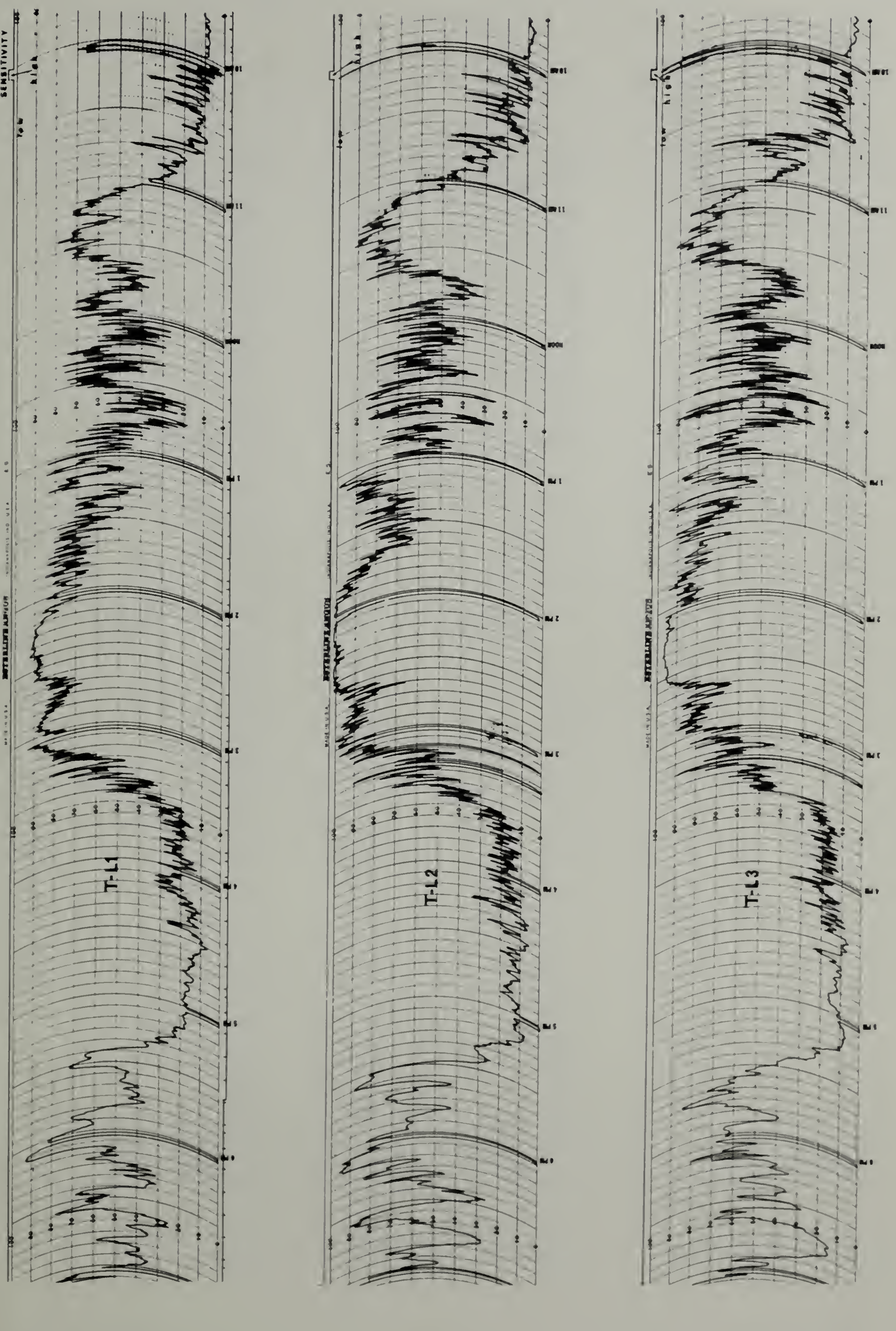


Figure 6b Fog of October 24, 1966, an example of rapid variations in fog density with time.

(continued)

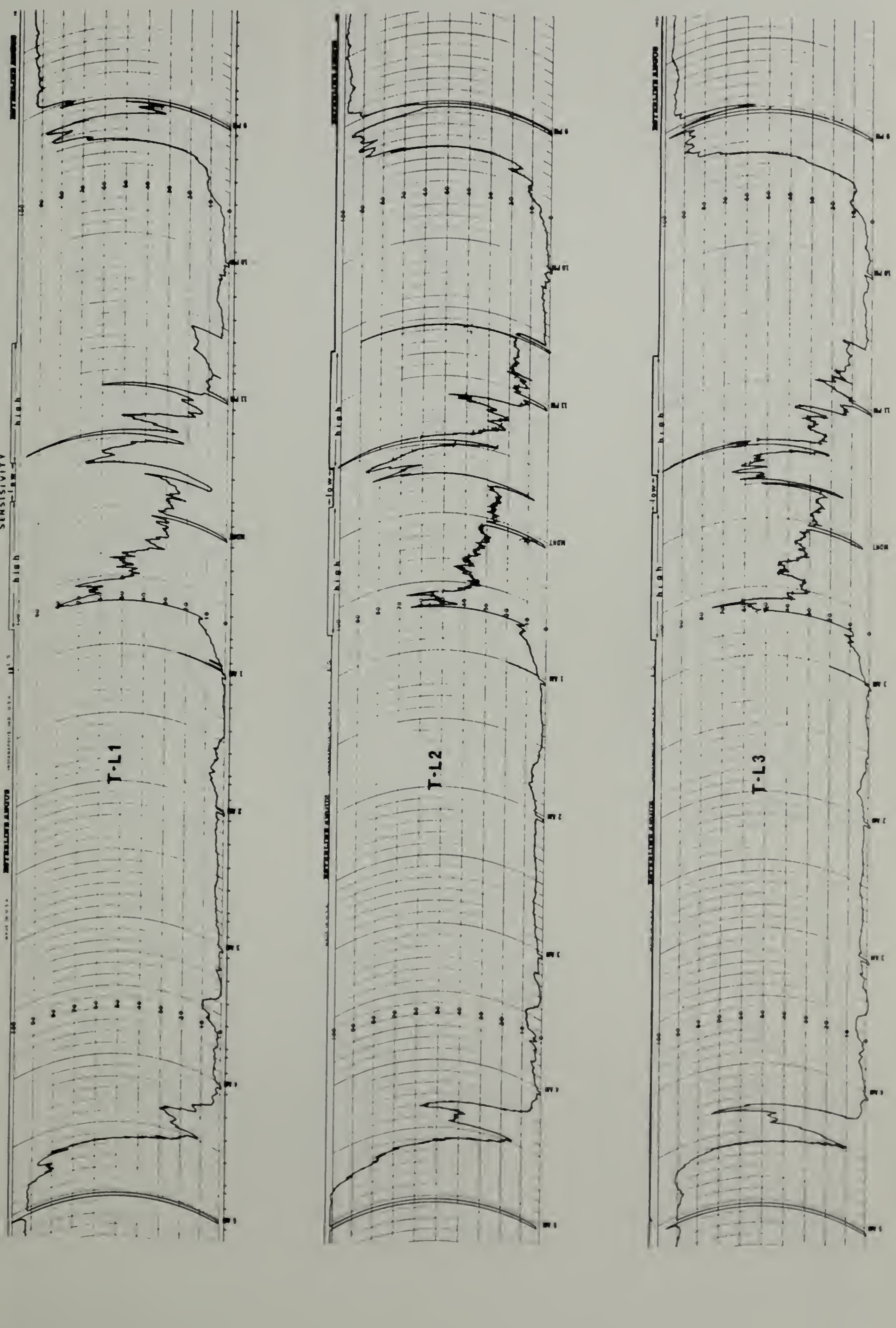
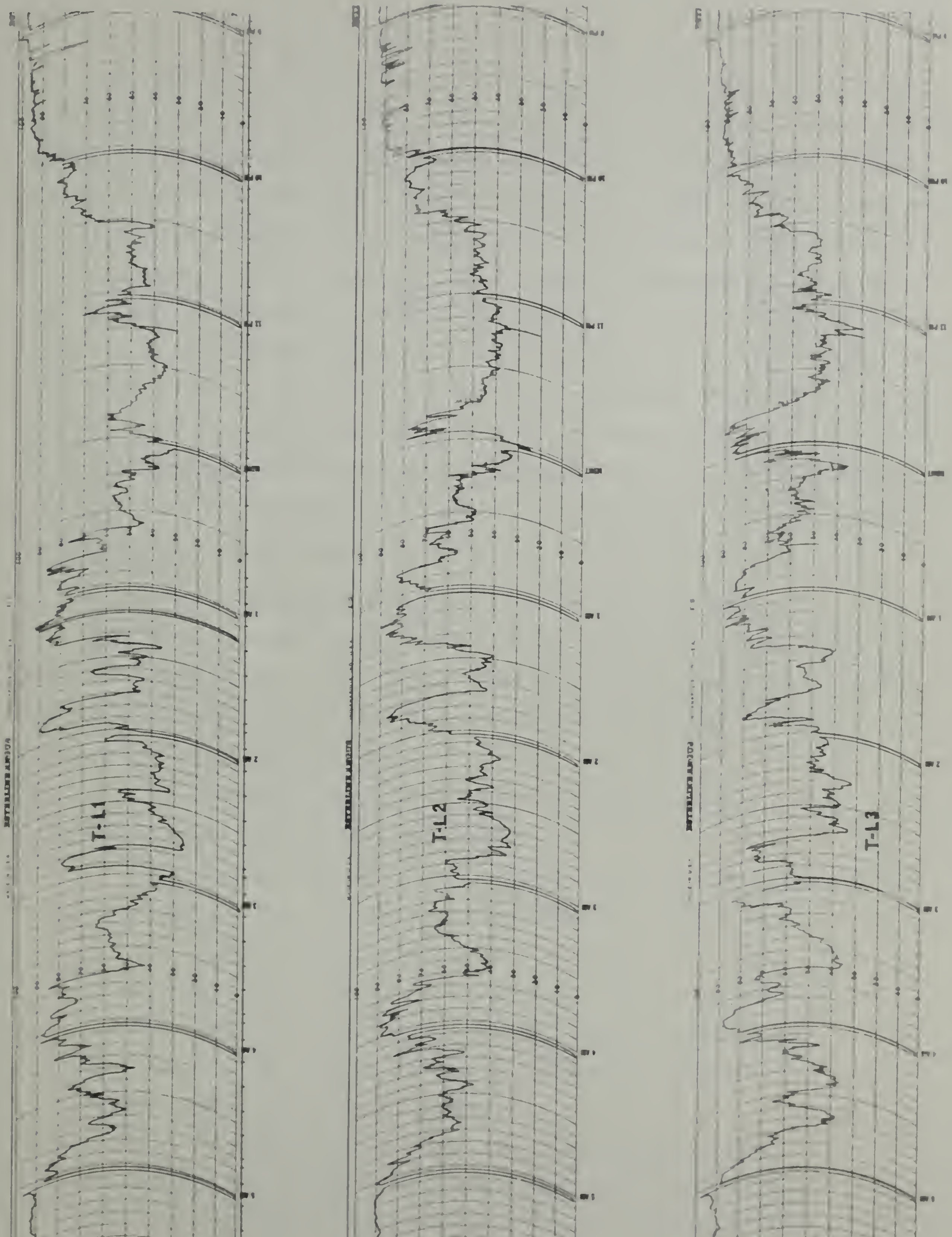


Figure 7 - Fog of October 24-25, 1966, a dense fog which was fairly uniform. The periods with the high sensitivity range show variations in dense, fairly stable fog.



[illegible] 28, 1966, an [illegible] fog [illegible]

5.6. Data Acquisition Equipment and Techniques

The analog records of the transmissometers were satisfactory for comparing with the laser data. In fog variability studies, chart drive speeds of 12 instead of 3 inches per hour during fog period is often useful. (A chart speed of 3 inches per hour was used in this study since the photopack records were intended to be the primary data.) Automatic range changing to high sensitivity is useful in dense fogs especially for periods during which the instruments must operate without attention. Digital readout of the measurements is more convenient than analog records for data analysis. In this test the photopack was intended to supply the digital data but the mechanical malfunction caused most of this data to be lost. However, even without malfunctions, delay in getting film processed is an inconvenience. Hence a digital printout of the data is preferable to the photographic recording of data.

5.7. Recommendations on Test Bed and Equipment

This test bed and installation is available for further use and should be considered for projects investigating the nature of coastal fog as well as future laser tests. Some possibilities for future utilization are as follows:

1. Tests in fog of lasers, transmission meters, backscatter meters, and fog detectors.
2. Visual observations for comparison with measuring instruments. This range could be extended to 2900 feet.
3. Evaluation of variations of fog with location on an airfield to better plan locations of transmissometers.
4. Evaluation of factors affecting the variability of coastal type fogs to determine the reliability of runway visual range measurements.
5. Evaluation of devices for determining slant visibility. For this purpose, the NBS slant visibility meter is installed in the vicinity of T-L2 which could be

used for measuring changes with elevation up to 750 feet.

In future studies printed readout for digital data instead of photographic records should be used whenever practical.

5.8. Information Pertinent to Improvements in Siting of Transmissometers.

No new information concerning siting and operation of transmissometers evolved as a result of the operation of the test bed. The tests confirmed previous work which indicated the need for using a closely spaced network of transmissometers when an accurate knowledge of the fog density over an extended area is required. The tests also confirmed previous studies which indicated the desirability of using isolating transformers in the transmissometer indicators so that the signal lever need not be grounded.

6. CLOSING OF PROJECT

6.1. End of Testing

All phases of the test plan were completed on November 5. Since this was near the end of the normal fog season, the Sperry Rand personnel left Arcata. The installation was left intact in case any phases of the test needed to be repeated. Since no repetitions were required, with the expectation that during the remainder of the year only limited amounts of fog conditions suitable for testing would occur, and with no specific needs for additional data, the test program was terminated.

6.2. Dismantling

Dismantling of the laser installation started on December 5. The laser equipment was shipped from Arcata on December 9. Earlier the photopack equipment had been returned to NAFEC. The 250-foot-baseline transmissometers were continued in operation with standby maintenance.

NBS Report 9506
March 1967
US COMM NBS DC